Environmental Factors and the Pulmonary Tuberculosis Cases in Bandung City in 2015-2019: an Ecological Study

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Introduction: *Pulmonary tuberculosis continues to be primary threat to public health by about 10.6 million cases in 2021. Among the countries, Indonesia being the second-largest contributor of tuberculosis cases. Bandung is the city in Indonesia which the incidence of pulmonary tuberculosis has been risen steadily since 2015. However, there is no information about the causes of the risen cases in Bandung city.*
Methods: *Using an ecological study methodology, this study investigated the relationship between the number of pulmonary tuberculosis cases and the environmental factors including of healthy house coverage, population density, and the coverage of families with clean and healthy living behaviors. The correlation test between variables was done with either the Spearman correlation test or the Pearson correlation test, based on the results of the normality test on each data.*
Results: *This study demonstrates a correlation between the coverage of healthy house and population density with the number of pulmonary tuberculosis cases, with both having a p-value of <0.001, but not the coverage of families with clean and healthy living behaviors.*
Conclusion: *It is advisable to empower local communities, utilize the technology as an empowerment facility, and utilize the role of public figures in health promotion to maximize the government efforts to prevent the pulmonary tuberculosis.*
Keywords*: Healthy house, PHBS, Population density, Pulmonary tuberculosis*

Faktor Lingkungan dan Kasus Tuberkulosis Paru-paru di Kota Bandung pada Tahun 2015-2019: Studi Ekologi

Latar Belakang: *Tuberkulosis paru masih menjadi ancaman utama bagi kesehatan masyarakat dengan jumlah kasus sebesar 10,6 di tahun 2021. Di dunia, Indonesia merupakan kontributor kasus tuberkulosis terbesar kedua. Kota Bandung merupakan kota di Indonesia yang insiden tuberkulosis parunya terus meningkat sejak tahun 2015. Namun, tidak terdapat informasi mengenai penyebab kenaikan kasus di Kota Bandung.*
Metode: *Menggunakan metode studi ekologi, studi ini meneliti hubungan antara kasus tuberkulosis paru dengan faktor lingkungan, termasuk cakupan rumah sehat, kepadatan penduduk, dan cakupan rumah tangga berperilaku hidup bersih dan sehat. Uji korelasi antar variabel akan dilakukan menggunakan uji korelasi Spearman atau uji korelasi Pearson, bergantung pada hasil uji normalitasnya masing-masing.*
Hasil: *Studi ini menunjukkan korelasi antara cakupan rumah sehat dan kepadatan penduduk dengan kasus tuberkulosis, dengan keduanya memiliki nilai p sebesar <0,001, namun tidak dengan cakupan rumah tangga berperilaku hidup bersih dan sehat.*
Kesimpulan. *Dari hasil studi ini, disarankan untuk memerdayakan komunitas lokal, memanfaatkan teknologi sebagai fasilitas pemberdayaan, dan memaksimalkan peran figur publik dalam upaya promosi kesehatan untuk memaksimalkan upaya pemerintah dalam usaha pencegahan tuberkulosis paru.*
Kata kunci*: Kepadatan penduduk, PHBS, Rumah sehat, Tuberkulosis paru, Usia*

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INTRODUCTION

Tuberculosis (TB) remains a significant public health concern worldwide, posing a threat to human health. This disease caused by the bacterium Mycobacterium tuberculosis and spreads through the airborne particles exhaled by infected individuals during coughing, sneezing, or spitting.[1] While TB can affect various organs such as skin, bones, brains, it predominantly targets the lungs.[2]

In 2021, it was estimated that the global burden of TB reached 10.6 million cases, with Indonesia ranking second in contributing to these numbers.[3] In Indonesia, there was 397.377 tuberculosis cases found in 2021.[4] In 2019, Bandung City recorded to be the second highest city in West Java with tuberculosis and the tuberculosis detection from 2017 to 2019 keeps increasing.[5,6]

The epidemiological triad model proposed by Rothman elucidates the interaction between variables influencing the pathogenesis of pulmonary tuberculosis.[7] Based on the theory, population density could be identified as a risk factor of pulmonary tuberculosis. Bandung City, with the highest population density in West Java (14,630 people/km^2), experiences expedited disease transmission and an amplified number of cases during outbreak and periods with insufficient health.[13–15] According to Aditama, as quoted by Suryani, high population density can also lead to inadequate living conditions and has the potential to accelerate the spread of pulmonary tuberculosis.[8]

Moreover, the correlation between housing conditions and TB incidence requires attention. The World Health Organization's Housing and Health Guidelines (HHGL) emphasize several key aspects for healthy houses, including residential density, indoor temperature, air quality, and cigarette smoke exposure.[9] Correspondingly, the Decree of the Minister of Health of the Republic of Indonesia Number 829/Menkes/SK/VII/1999 outlines housing health requirements to promote healthy living spaces.[10] In 2019, approximately 70.92% of households in Bandung City met the healthy house criteria.[6] It can be described that a lack of air ventilation will reduce air exchange and the entry of sunlight into the house, or non-permanent floor conditions have the potential to create a damp and dusty home environment.[11,12]

Furthermore, the role of a clean and healthy lifestyle (or PHBS in Bahasa Indonesia) within the community cannot be overlooked in the pursuit of curbing TB incidence. Behavioral factors significantly impact overall health, with PHBS serving as a potential solution to create hygienic living environments for individuals, families, and communities.[13] In 2019, 67.88% of households in Bandung City demonstrated adherence to PHBS practices.[6] The practice of PHBS is one of the risk factors for causing pulmonary tuberculosis, as evidenced by research that has found a connection between the two, where locations that tend to practice PHBS have low cases of pulmonary tuberculosis.[14]

METHOD

Participant and Study Design

This study was done with an ecological study design, focusing on examining the number of pulmonary tuberculosis cases in the Bandung City, along with the independent variables of population density, the percentage of households practicing clean and healthy living behavior (PHBS), and the coverage of healthy houses. There are no covariate variables in this study. The variables used in this study were selected based on the literature study results from several previous studies.

Measurements and Procedures

The data for these four variables were collected over a five-year period, specifically from 2015 to 2019. The data regarding the pulmonary tuberculosis cases, the coverage of households practicing PHBS, and the coverage of healthy houses will be obtained from the Bandung City Health Office. On the other hand, population density data will be acquired from the Central Bureau of Statistics of Bandung City. All data used in this study are secondary data. The cases that were taken were the lung tuberculosis cases for Bandung City Residents who were confirmed bacteriologically and clinically and could be traced to their domicile. Meanwhile, healthy household coverage, households practicing PHBS, and population density data were the entire population of Bandung City, as recorded by the Central Bureau of Statistics of Bandung City.

Statistical Analysis and Ethical Clearance

To ensure comprehensive analysis, the study employs a sub-district level analysis, with the unit of analysis being the thirty sub-districts encompassed within the Bandung City area. The test was done using "IBM SPSS Statistic 22" software. The four variables being studied are numerical data; therefore, univariate analysis is conducted to obtain the mean, median, standard deviation, minimum value, and maximum value. The normality test is conducted using the Kolmogorov-Smirnov test, and the test results will indicate whether the p-value < 0.05 (not normal) or the p-value ≥ 0.05 (normal). The correlation test was done with either the Spearman correlation test or the Pearson correlation test, based on the results of the normality test on each data. The correlation between two variables will be considered to have a significant correlation if the p-value ≤ 0.005, and the value of r will describe the direction of the correlation between two variables. This study has met the ethical review conducted by The Research and Community Engagement Ethical Committee Faculty of Public Health Universitas Indonesia with reference number Ket-530/UN2.10.D11/PPM.00.02/2023.

RESULTS

Descriptive of Pulmonary Tuberculosis Cases and Environmental Factors

The data of pulmonary tuberculosis cases are organized based on the sub-districts where the patients reside. According to the data, there were a total of 5,424 cases of pulmonary tuberculosis patients whose residential information could be traced in 2015. In 2016, this number increased to 5,458 cases, and further rose to 6,962 cases in 2017. The upward trend in the detection rate continued in 2018, reaching 7,722 cases, and peaked at 8,901 cases in 2019. The graph illustrates that the number of tuberculosis cases in the Bandung City has consistently risen over the five-year period (Figure 1A).

In 2015, the coverage of healthy houses in the city of Bandung was reported to reached 74.02%. The following year, in 2016, it increased slightly to 74.30%. The upward trend continued, and in 2017, the coverage of healthy houses reached 78.29%. Subsequently, in 2018, it further improved to 85.91%. However, in 2019, the coverage of healthy houses decreased to 70.91% (Figure 1B).

In 2015, the coverage of households with clean and healthy living behavior (PHBS) was reported to reached 65.91%. The following year, in 2016, it remained the same at 65.91%. However, in 2017, the coverage of households with PHBS continued to increase to 67.79%. Finally, by 2019, the coverage of households with PHBS had reached 67.88% (Figure 1C).

Based on the data obtained, the population density in Bandung City in 2015 was recorded as 14,831 people/km^2. It showed a slight increase in the subsequent years, reaching 14,832 people/km^2 in 2016, 14,930 people/km^2 in 2017, and 14,940 people/km^2 in 2018. However, in 2019, the population density decreased to 14,549 people/km^2 (Figure 1D).

Correlation of Pulmonary Tuberculosis Cases and Environmental Factors

Based on the results of the correlation test, it was observed that two variables exhibited a significant relationship with the number of pulmonary tuberculosis cases, the coverage of healthy houses and population density. Both variables demonstrated a p-value of 0.000, indicating a strong statistical significance. The relationship between the coverage of healthy houses and the pulmonary tuberculosis cases is of moderate strength with an inverse relation. This means that as the coverage of healthy houses increases, there is a corresponding decrease in the pulmonary tuberculosis cases. On the other hand, the relationship between population density and the pulmonary tuberculosis cases has a positive relation, indicating that as population density rises, the incidence of pulmonary tuberculosis also increases. However, the variable of coverage of households with PHBS displayed no significant relationship with the incidence of pulmonary tuberculosis, as the correlation was not statistically significant (Table 1).

Based on the correlation test conducted at the sub-district level, it was

observed that the variable coverage of healthy houses and the pulmonary tuberculosis cases did not show a significant relationship in each sub-district, with a p-value exceeding 0.05. As for the variable coverage of households with PHBS, two sub-districts, namely Gedebage Sub-District and Sumur Bandung Sub-District, could be seen to have a significant correlation between the two variables. However, the direction of the relationship differed in these two sub-districts.

In Gedebage Sub-District, there was an inverse relationship, where higher coverage of households with PHBS correlated with a decrease in the pulmonary tuberculosis cases. In contrast, in Sumur Bandung Sub-District, there was a unidirectional relationship, where higher coverage of households with PHBS correlated with an increase in the number of pulmonary tuberculosis cases. For the variable population density and the pulmonary tuberculosis cases, eight subdistricts showed a significant relationship between the two variables, namely Bandung Kidul Sub-District, Buahbatu Sub-District, Rancasari Sub-District, Bojongloa Kidul Sub-District, Astanaanyar Sub-District, Batununggal Sub-District, Cibeunying Kidul Sub-District, and Sumur Bandung Sub-District. The direction of the relationship in all these sub-districts was unidirectional, indicating that higher population density was correlated with a higher incidence of pulmonary tuberculosis in each district (Table 2).

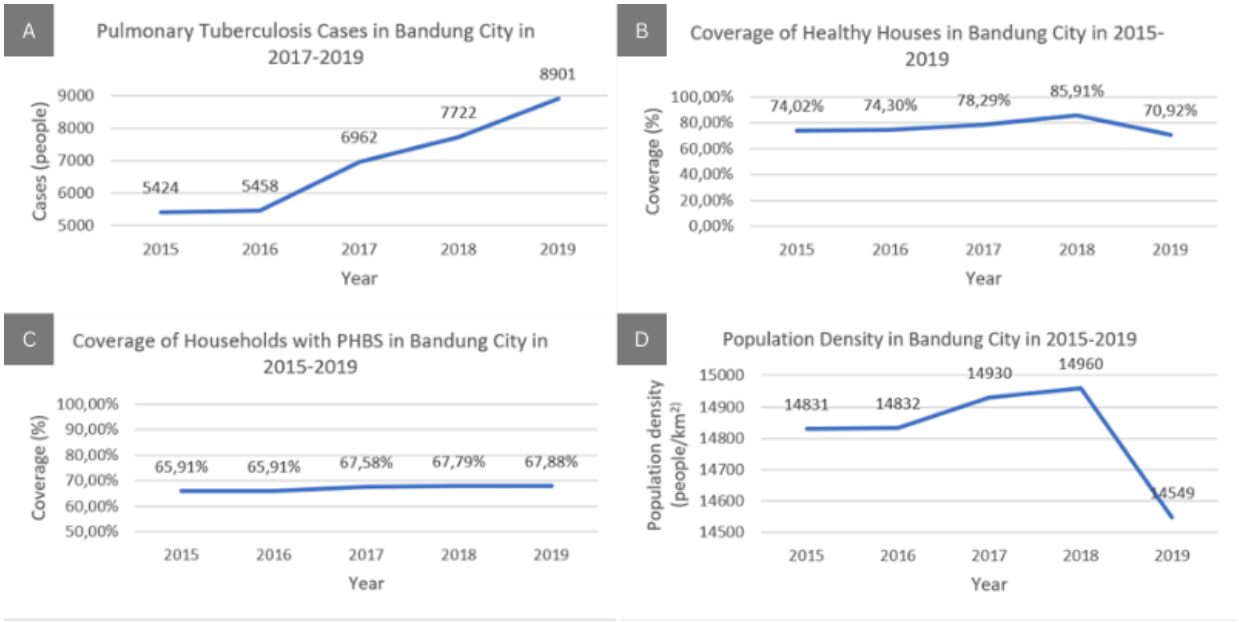

Figure 1. (A) Pulmonary Tuberculosis Cases in Bandung City in 2017-2019. (B) Coverage of Healthy Houses in Bandung City in 2015-2019. (C) Coverage of Households with PHBS in Bandung City in 2015-2019. (D) Population Density in Bandung

Table 1. Correlation test Result Between Independent Variables and the Number of Pulmonary Tuberculosis Cases in Bandung City in 2015-2019

Variable	p-value	Coefficient of Correlation
Coverage of healthy houses	0,000	-0,317
Coverage of households with PHBS	0,876	-0,013
Population density	0,000	0,781

*significant ($p \leq 0,05$)

Table 2. Correlation Test Results Between Independent Variables and Pulmonary Tuberculosis Cases Based on Sub-Districts in Bandung City

Sub-Districts	Coverage of Healthy Houses		Coverage of Households with PHBS		Population Density	
	p-value	Coefficient of Correlation	p-value	Coefficient of Correlation	p-value	Coefficient of Correlation
Bandung Kidul	0,794	-0.163	0,219	0.667	0.005*	0,975
Buahbatu	0,803	0,155	0,166	-0,724	0.005*	0,975
Ranasari	0,076	0,838	0,833	-0,132	0.005*	0,975
Gedebage	1,000	0,000	0,005*	-0,975	0,805	0,154
Penyileukan	0,265	0,619	0,142	0,753	0,553	-0,359
Cibiru	0,163	0,728	0,694	-0,243	0,553	-0,359
Cinambo	0,498	0,406	0,866	0,105	0,553	0,359
Ujung Berung	0,579	0,337	0,289	0,596	0,089	0,821
Arcamanik	0,629	0,296	0,426	-0,468	0,935	-0,051
Mandalajati	0,900	0,078	0,200	0,687	0,219	0,667
Antapani	0,765	-0,186	0,805	0,154	0,935	-0,051
Bandung Kulon	0,114	-0,788	0,164	0,727	0,935	-0,051
Babakan Ciparay	0,516	-0,390	0,434	-0,462	0,0683	-0,252
Bojongloa Kidul	0,067	-0,852	0,089	0,821	0,005*	0,975
Bojongloa Kaler	0,918	-0,065	0,930	-0,055	0,561	-0,352
Astanaanyar	0,594	-0,324	0,573	0,342	0,014*	0,947
Regol	0,413	0,480	0,235	-0,650	0,322	0,564
Lengkong	0,930	-0,055	0,535	0,359	0,935	-0,051
Batununggal	0,886	-0,089	0,219	-0,667	0,005*	0,975
Kiaracondong	0,758	0,191	0,391	-0,500	0,168	0,723
Cibeunying Kidul	0,859	-0,111	0,244	-0,640	0,005*	0,975
Cibeunying Kaler	0,261	-0,624	0,690	0,246	0,935	-0,051
Sumur Bandung	0,198	-0,689	0,035*	0,904	0,030*	0,913
Bandung Wetan	0,830	0,134	0,317	0,569	0,935	0,051
Coblong	0,586	0,332	0,316	-0,570	0,553	0,359
Cidadap	0,745	0,201	0,285	0,600	0,935	0,051
Andir	0,570	-0,345	0,718	-0,224	0,805	-0,154
Cicendo	0,354	-0,534	0,267	0,618	0,935	-0,051
Sukajadi	0,594	-0,325	0,064	0,856	0,935	-0,935
Sukasari	0,418	0,476	0,714	-0,226	0,935	-0,051

*significant ($p \leq 0,05$)

DISCUSSION

The data used in this study includes all cases of pulmonary tuberculosis, regardless of whether they are new cases or cases with a history of treatment, from individuals domiciled in Bandung City. However, there were cases where the origins of the people with pulmonary tuberculosis could not be traced, which means that the data used may not fully represent the entire pulmonary tuberculosis cases in the city and its sub-districts. Over the period from 2015 to 2019, the incidence of pulmonary tuberculosis has consistently increased.

The coverage of healthy houses can be determined by dividing the number of houses that meet the criteria for healthy houses by the total number of recorded houses.[6] The assessment of healthy houses includes evaluating the physical and biological quality of water, air, food, soil, as well as facilities and house buildings. Data on the coverage of

healthy houses in Bandung City indicate a steady increase from 2015 to 2018. However, there was a decrease in the coverage of healthy houses in 2019, possibly due to the inclusion of healthy latrine criteria in the assessment, which affected the overall results.

The results of the correlation test in this study demonstrated a significant relationship between the coverage of healthy houses in Bandung City and the pulmonary tuberculosis cases. However, the relationship between the coverage of healthy houses and the pulmonary tuberculosis cases could not be observed in the correlation test based on sub-districts, possibly due to the limited amount of data available for analysis.

The correlation between healthy house coverage and the number of pulmonary tuberculosis cases shown in this study in line with the findings of research in Semarang City, which demonstrated the correlation between several healthy house assessment criteria, including the size of living room ventilation, living room lighting, family room lighting, bedroom lighting, and humidity, with the pulmonary tuberculosis.[15] On the other hands, a research in West Java contradicts the results in this study, as it does not indicate a correlation between healthy house and the BTA-positive pulmonary tuberculosis cases from 2013 to 2017.[16]

The theory suggests that the tuberculosis is more likely to spread among individuals who spend a significant amount of time together each day, such as family members.[17] The resistance of tuberculosis bacteria in the environment can be influenced by factors such as sunlight and humidity. The presence of ventilation and windows can indirectly affect sunlight, humidity, and house temperature, thereby potentially impacting the occurrence of tuberculosis.[18] Proper ventilation and exposure to sunlight can reduce bacterial concentrations in the air, and sunlight plays a role in killing M. tuberculosis bacteria. Additionally, ongoing exposure to high temperatures can also have a detrimental effect on these bacteria.[19] The physical condition of a house, including the walls, ceiling, and floor, can also influence the incidence of a diseases. These factors can affect humidity and particulate matter in the air, potentially impacting the spread of tuberculosis.[20] Thus, ensuring healthy conditions in houses is crucial for promoting community health.

The coverage of households with clean and healthy living behaviors (PHBS) is calculated by dividing the number of households implementing such behaviors by the total number of households monitored.[6] In Bandung City, the coverage of households with PHBS has shown a consistent increase over the years. The correlation test results between the variable coverage of households with PHBS and the pulmonary tuberculosis cases in Bandung City did not reveal a significant relationship between the two variables. However, at the sub-district level, significant relationships were found in Gedebage Sub-District and Sumur Bandung Sub-District. In Gedebage Sub-District, a reverse relationship was observed, meaning that higher coverage of households with PHBS resulted in a lower pulmonary tuberculosis case.

Conversely, in Sumur Bandung District, a unidirectional relationship was observed, indicating that higher household coverage with PHBS was correlated with a higher pulmonary tuberculosis case. The differing results at the sub-district level may be attributed to the limited amount of data available for analysis.

The results of the correlation test in Bandung City, which do not show a significant correlation between the family with clean and healthy living behaviors coverage and the number of pulmonary tuberculosis cases, align with the research in Waru District, Sidoarjo Regency, which also does not indicate a correlation between clean and healthy living behaviors and the occurrence of pulmonary tuberculosis.[21] Meanwhile, there is research that shows a correlation between these two variables, such as the study conducted in Medan City, which found a significant correlation between community behavior and the number of pulmonary tuberculosis cases.[22]

According to the theory, implementing a clean and healthy living behaviors can indirectly contribute to improving people's quality of life and supporting public health.[23] The presence of facilities that support healthy house is complemented by resident’s adherence to clean and healthy living behaviors. For instance, the simple habit of opening windows to allow sunlight to enter the house and facilitates air circulation can be beneficial. On the other hand, smoking habits can significantly impact the number of tuberculosis cases. Smoking increases the risk

of developing tuberculosis and other lung diseases, not only for active smokers but also for those exposed to secondhand smoke as passive smokers.[24]

Population density is a crucial factor in understanding the incidence of pulmonary tuberculosis in an area. It is calculated by dividing the total population in a specific area by the land area of that region. In the city of Bandung, population density showed a consistent increase from 2015 to 2018, but there was a significant decline in 2019. This decline could be attributed to variations in data sources used in several publications by the Central Bureau of Statistics (BPS) in Bandung, which some of those sources come from data projection for Indonesia's population.

The correlation test results in this study revealed a highly significant relationship between population density and the pulmonary tuberculosis cases in Bandung City, which showed a very strong correlation between the two variables. The findings suggest that higher population density in an area is linked to a higher pulmonary tuberculosis case. However, when examining the correlation test based on sub-districts, the significant correlation was observed only in several sub-districts, namely Bandung Kidul Sub-District, Buahbatu Sub-District, Rancasari Sub-District, Bojongloa Kidul Sub-District, Astanaanyar Sub-District, Cibeunying Kidul Sub-District, and Sumur Bandung Sub-District. The limited number of units of analysis used in the sub-district level correlation test might have affected the visibility of the distribution of pulmonary tuberculosis cases based on population density.

The significant correlation between population density and the occurrence of pulmonary tuberculosis, as obtained from this study, is consistent with research conducted in Semarang City, which demonstrates that the distribution of pulmonary tuberculosis cases tends to follow the population density distribution.[25] Another study conducted in Jakarta also provides evidence of a strong relationship between population density and new cases of pulmonary tuberculosis.[26] On the other side, this study does not align with research conducted in Kendari City in 2013-2015, where no correlation was found between population density and BTA-positive pulmonary tuberculosis.[27]

Population density is considered a risk factor for pulmonary tuberculosis due to the increased likelihood of exposure to infected individuals in densely populated areas.[28] Additionally, higher population density can lead to increased occupancy density, potentially compromising living conditions. Ideally, the minimum bedroom area should be 8 m^2 for a maximum of two people over the age of 5 years.[10,29] Excessive occupancy density can impact the availability of oxygen and adversely affect the comfort and health of the occupants. This aspect is closely linked to the social and economic status of families, as their capacity to achieve adequate housing density varies.[30]

Research Limitation

This study is unable to elucidate the correlation between risk factors and individuals or establish cause-and-effect relationships between variables. These limitations stem from the ecological study methods employed, which rely on aggregate data. Additionally, when inputting data on pulmonary tuberculosis cases from the Bandung City Health Office, some respondents are not registered with their respective sub-districts. Consequently, this affects the number of cases in each sub-district because some respondents cannot be categorized within their respective sub-districts.

CONCLUSION

The prevalence of pulmonary tuberculosis in the Bandung City in 2015-2019 continues to increase every year. The coverage of households with PHBS shows a trend that tends to increase every year. Population density has increased from 2015 to 2018, but there has been a significant decrease in 2019. The trend for the coverage of healthy houses has continued to increase from 2015 to 2018 but has experienced a decline in 2019. The results of the correlation test showed that there was a relationship among the prevalence of tuberculosis with the coverage of healthy houses and population density, while the variables that did not show a relationship with the prevalence of pulmonary tuberculosis were coverage of households with PHBS.

For further research, it is advised to be done by examining the related variables for each individual in order to be able to describe events at the individual level. The Bandung City Health Office can pursue health promotion programs trough programs that

directly involve the community, such as independent house health monitoring. In addition, the government can use public figures as examples of clean and healthy living behaviors to the community. It is also advised to the Bandung City Health Office to collaborate with other organization from various sector to handle the pulmonary tuberculosis along with its risk factors.

AUTHOR CONTRIBUTIONS

Conceived and designed the study by CNA, RAW; CNA performed the study; CNA analyzed the data; CNA and RAW wrote the initial manuscript. FK review and editing the manuscript. The authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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